Vortex Generator Flight Tests — Cruise Performance

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Around the pilots lounge you'll frequently hear those with vortex generators installed on their aircraft claim that there is no affect on cruise performance. I view such statements with a healthy dose of skepticism. After all, nearly anything you stick on an aircraft, be it an antenna, a wing walk, an outside air temperature probe or a vortex generator creates drag. For a given power available, an increase in drag results in a decrease in cruise velocity. Another way of looking at it is; if vortex generators did not produce drag, then they would not need to be glued to the wing – they'd just sit there!

The aircraft Flight tests were conducted before and after the installation of the Beryl D'Shannon (BDS) vortex generators (VGs). (See the Jan/Feb 2002 WBS Newsletter for a flight test report on stall performance with VGs.) The aircraft is a 1969 Model E33A Bonanza shown in Figure 1 with the VGs installed. The aircraft is powered with a remanufactured Continental IO-520BB engine equipped with GAMI balance fuel flow injectors. A recently overhauled McCaully 3A32C76-S-MR three blade propeller is fitted. At the time of the flight test both engine and propeller had been operated for less than 200 hours.

The flight tests Both flight tests were conducted by the same pilot, data recorder and observer. All loose equipment in the aircraft was carefully weighted. The same equipment was aboard the aircraft for both flight tests. Takeoff weight was 3202 ± 2 lbs for both flights. During the flights, while data was being taken, the weight decreased from 3177 lbs to 3084 lbs as fuel was consumed. At take off, the center of gravity was mid-range at 82.5 inches aft of the datum and varied from 82.6 to 82.8 inches aft of datum during the flight tests. The tests

Figure 1. Vortex generators.

were conducted at a pressure altitude of 6000 feet for a range of power availables from 43% to 75% as determined using the Continental IO-520BB power curves corrected for temperature. The engine was consistently leaned to 100° F rich of peak EGT using an Alcor six probe EGT.

True airspeed was determined using GPS and the horseshoe heading technique. The horseshoe heading technique uses the GPS ground speed observed in steady level flight during three legs each at a 90° heading from the previous leg to eliminate the effect of wind (see Figure 2)†. In Figure 2, V_1, V_2 and V_3 are the GPS ground speeds on the three legs, V_T is the TAS, V_N is the northerly component of the wind and V_W is the westerly component of the wind.

† see http://web.usna.navy.mil/~dfr/horseshoehead.pdf for a derivation and explanation of the horseshoe heading technique.

A Century II autopilot in heading mode and an S-TEC 60 PSS altitude hold were engaged to minimize both altitude and heading excursions. On each leg both the aircraft indicated airspeed (IAS) and GPS ground speed were allowed to stabilize prior to data acquisition. As a crosscheck, a second GPS ground speed was taken approximately 30 seconds later.

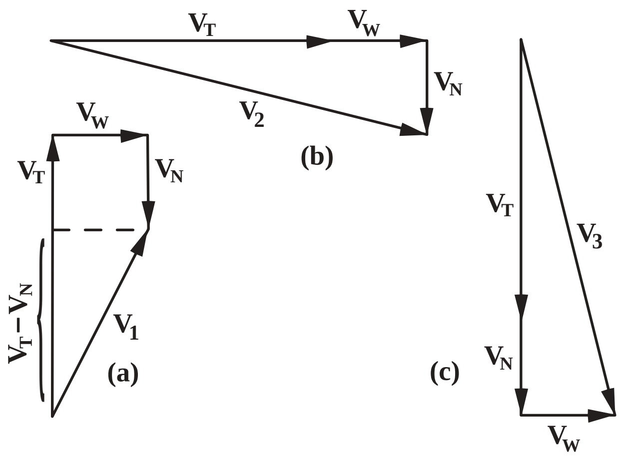

Figure 2. Horseshoe heading technique.

The horseshoe heading technique yields simple equations, which can easily be coded into a spreadsheet, for both the true airspeed and wind speed and direction. Here we are only interested in TAS given by

$$V_T = \frac{1}{2}\sqrt{P \pm \sqrt{P^2 - 2(2Q^2 - 2RQ + R^2)}} \qquad (1)$$

where $P = V_1^2 + V_3^2$, $Q = V_2^2 - V_3^2$ and $R = V_1^2 - V_3^2$ and again V_1, V_2 and V_3 are the GPS ground speeds on the three legs as shown in Figure 2.

Table 1. With VGs

% BHP	TAS mph	TAS kts
44.0	127.6	111.0
50.5	151.0	131.3
57.0	167.2	145.5
65.0	182.3	158.6
69.0	188.3	163.8
72.5	191.6	166.7

Table 2. Without VGs

% BHP	TAS mph	TAS kts
42.5	117.6	102.3
45.0	138.4	120.4
51.9	161.2	140.3
59.6	177.3	154.2
66.5	189.4	164.7
71.5	196.0	170.5
75.0	197.7	172.0

Results Tables 1 and 2 give the true airspeed (TAS) for various percentages of available engine power (brake horsepower, BHP) with and without VGs. Although it is more common to use power required versus TAS, pilots typically think in terms of available BHP, hence the choice of percent BHP. The results from Tables 1 and 2 are shown graphically in Figure 3. Figure 3 clearly shows that the VGs generate drag which results in a cruise TAS reduction. The reduction in cruise TAS for various percentages of available BHP are shown in Table 3 and graphically in Figure 4. For example, at a pressure altitude of 6000 ft at 65% BHP the VGs result in a reduction in cruise TAS of 5.1 mph (4.4 kts) or 2.7%. Notice, however, from Figure 4 that the loss of TAS decreases with increasing TAS.

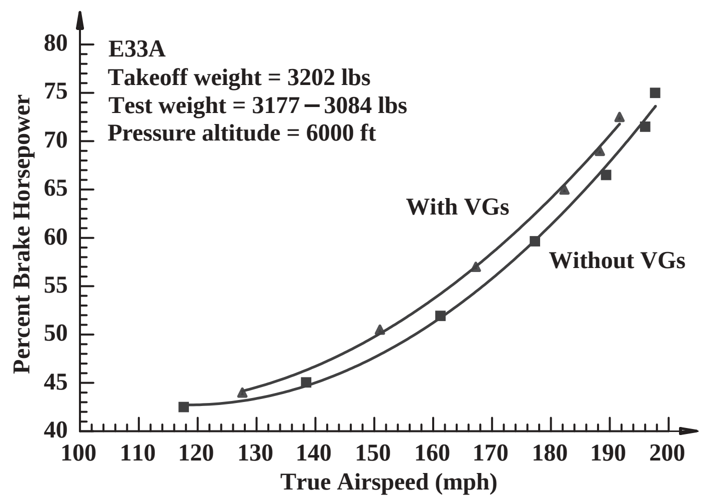

Figure 3. Percent brake horsepower versus true airspeed.

Table 3. Reduction in TAS With VGs Fitted

% BHP	TAS mph	TAS kts
45	9.1	7.9
50	7.2	6.3
55	6.3	5.5
60	5.6	4.9
65	5.1	4.4
70	4.6	4.0
75	4.2	3.7

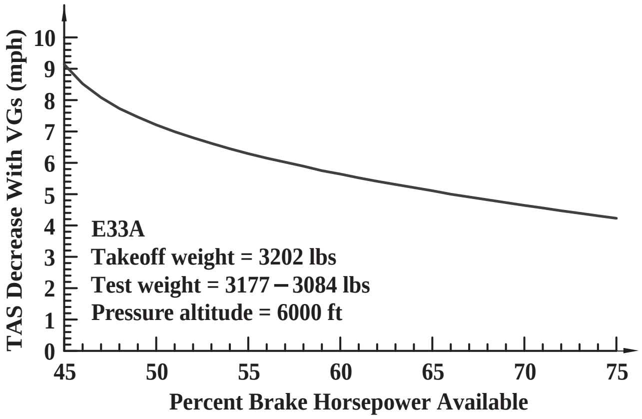

Figure 4. Cruise TAS reduction with vortex generators.

Conclusions The addition of vortex generators results in increased drag and hence decreased cruise true airspeed and range. On a flight with a three hour leg at a pressure altitude of 6000 feet at 65% power in no wind conditions the decrease in range is approximately 13.3 nm which results in an increase of about five minutes in flight time. Considering the decrease in power off stall speed and excellent aileron control reported in the previous article, these small decreases in cruise TAS may be acceptable.